A DECISION SUPPORT TOOL FOR MAINTENANCE SCHEDULING OF KAPLAN TURBINES

A case of Bujagali Hydropower Plant

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A project implementation submitted to the Department of Water Resources Engineering in partial fulfilment of the requirement for the award of the Bachelor of Science in Water Resources Engineering of Busitema University

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ABSTRACT

This implementation report presents a maintenance scheduling tool for Kaplan turbines. Therein is the system decomposition of the Kaplan turbine and a Failure Modes, Effects, Criticality and Diagnostic Analysis of its components. As a result, a process map was developed in form of an adjacency matrix and a figure of component interconnectivity. Weibull analysis was invoked on the maintenance data and a table that shows the component details discovered. The shape parameters which indicate the stage of the turbine components was developed, thus guidance for the type of maintenance to give to a component. Guide vanes were discovered as the most vulnerable component with a repair frequency of nearly a month, a shape parameter of 0.6141 and a scale parameter of 10 days, implying that they are still in the burn in stage, and possible remedies given so as to tame the water quality. Furthermore, a diagnostic tool was developed using the Bayesian Networks and Hidden Markov chain. The model was established in terms of transition and emission probabilities, which were given in terms of matrices. Program Evaluation and Review Technique (PERT) analysis was used to obtain maintenance project duration for the critical path for the maintenance of each of the components. Later this knapsack problem was be fed into a Genetic Algorithm to optimize the maintenance schedule, putting into consideration the maintenance window together with the flows and power prediction peak and off-peak periods. The intelligent optimization models were be developed in MATLAB and thereafter the algorithms tested on a case of Bujagali hydropower plant.

Keywords: vertical Kaplan turbines, fault diagnosis, Bayesian networks, Hidden Markov chains, maintenance scheduling

DECLARATION

I the undersigned, declare that this implementation report is my original work except where due acknowledgement has been made. I declare that this work has never been submitted to this university or any other institute for funding or for partial fulfillment for any award.

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APPROVAL

This is a research implementation report submitted as a partial fulfilment for the award of Bachelor degree of science and Water Resources Engineering of Busitema University, with my approval as the academic supervisor(s).

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DEDICATION

This report is dedicated to any of you who has added that extra oomph in my academic journey.

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LIST OF ACRONYMS OR ABBREVIATIONS

ANN – Artificial Neural Network

ANOVA – Analysis of Variance

CBM – Condition Based Monitoring

cdf – cumulative distribution function

DNN – Deep Neural Network

EST – Excel Solver Tool

FDD – Fault Detection and Diagnosis

GUI - Graphical User interface

GA – Genetic Algorithm

HTG – Hydro Turbine Generator

MATLAB – Matrix Laboratory

MTBF – Mean Time Between Failures

MTTF – Mean Time to Failure

MTTR – Mean Time to Repair

pdf- probability density function

SCADA – Supervisory Control and Data Acquisition

SYMBOLS AND NORMENCLATURE

β - Weibull shape parameter

λ - Weibull scale parameter

t - time of consideration

μ – Weibull location parameter

t_{safe} - safe operational time from the start of the system after repair

t_{safe} – remaining useful life to the target reliability

R - reliability

$t_{RULSafe}$ – remaining useful life for an individual component

1.0 CHAPTER ONE

This chapter entails the back ground to the study, statement of the problem, justification, objectives of the study, scope of the study: including the conceptual, geographical and time scope, the significance of the study.

1.1 Background

The conjunctive use of renewable energy and more efficient technologies has become an appropriate solution to escalated energy demands. The International Hydropower Association coins that hydropower stands out, by producing more than all the other renewables-based generations, combined together. It has an installed global capacity of 1300 GW and having nearly 4500 TWh of power generation as of 2020, which is approximately a sixth of global electricity generation (IHA, 2022). Other renewables like wind, solar are intermittent, making hydropower the most powerful and reliable source, capable of stabilizing the electrical grid. However, HPPs require great flexibility in their operation, owing to the variable demand in the market as well as the limited electrical storage system (Michalski et al., 2022).According to the International Renewable Energy Agency (Katutsi et al., 2021), hydropower accounted for 45.6% (1331.9 GW) of the global cumulative installed power capacity from renewable energy resources, while wind energy, solar energy, bioenergy, and geothermal energy contributed 25.1%, 24.4%, 4.3% and 0.5%, respectively. Asia accounted for 42.6% (or 566.7 GW), while Africa accounted for 2.8% (or 37.3 GW) of global installed hydropower. In terms of installed capacity, Ethiopia, with 4074 MW, is ranked first, while Uganda ranks 13th in hydropower development in Africa.

Despite the robustness of HPPs, they are not immune against sudden catastrophic failures, which end up generating long downtime, thus taxing their reliability, availability and maintainability and sometimes presenting a serious threat to the life of the Operation and Maintenance team especially for underground powerhouses. Not forgetting the indirect costs such as revenue losses. Among all the subsystems of a Hydropower Plant (HPP), the turbine suffers more from the aforementioned variations in operational regime (Michalski et al., 2022). There are four major defects of the Kaplan turbines namely; cavitation, erosion, fatigue and material defects. Occurrence of cavitation is the main source of vibration which exists due to turbulent waterflow in the water blades (kumar & Singal, 2015).

More components added and the project can be explored for more systems of the Hydropower Plant so as to broaden the scope. Real time update of the database can be incorporated into the system so as to reduce on the manual work of updating the excel. The location parameter adjustment so as to cater for those components that have not been repaired but were in operation before.

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